Draft Info Sheet Outline

Energy Storage Safety

An informational fact sheet prepared by the DOE Energy Storage Safety Working Group

Intro

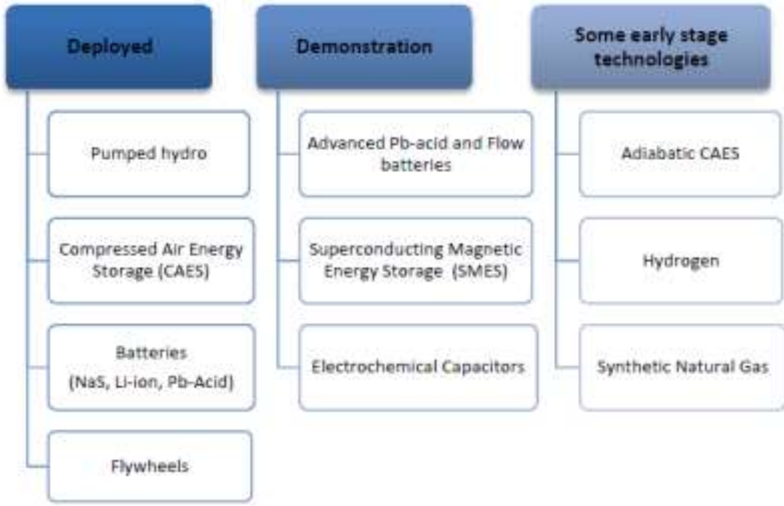
Energy storage is emerging as an integral component to a resilient and efficient grid through a diverse array of potential applications. The evolution of the grid that is currently underway will result in a greater need for services best provided by energy storage, including energy management, backup power, load leveling, frequency regulation, voltage support, and grid stabilization. The increase in demand for specialized services will further drive energy storage research to produce systems with greater efficiency at a lower cost, which will lead to an influx of energy storage deployment across the country. To enable the success of these increased deployments of a wide variety of storage technologies, safety must be instilled within the energy storage community at every level and in a way that meets the need of every stakeholder.

Safety of any new technology can be broadly viewed as having three intimately linked aspects, as follows: 1) the system must be engineered and validated to the highest level of safety; 2) techniques and processes must be developed to respond to incidents when they occur; and 3) best practices and system requirements must then be reflected in Codes Standards and Regulations (CSR) so that there is uniform, consistent, understandable and enforceable criteria that must be satisfied when designing, building, testing, and deploying systems.

Energy storage types and maturity

Each storage technology has unique performance characteristics that make it optimally suitable for certain grid services; however, the technologies are each at different maturity levels and are each deployed in varying amounts. These differences must be taken into consideration when addressing safety because the level of risk increases as the level of maturity decreases or the level of deployment increases. The different levels of maturity and deployment also illustrate which systems must immediately be validated as safe. Figure 2 lists technologies based on their present degree of adoption.

Pumped hydro is one of the oldest and most mature energy storage technologies and represents 95% of the installed storage capacity. Other storage technologies, such as batteries, flywheels and others, make up the remaining 5% of the installed storage base, are much earlier in their deployment cycle and have likely not reached the full extent of their deployed capacity. Among these deployed storage technologies, the DOE OE Strategic Plan for Energy Storage Safety focuses primarily on batteries, with some attention to flywheels due to the rapid growth seen in these two relatively new grid-scale technologies.



Safety codes and standards

Standards and codes have a direct impact on the cost of an ESS and its installation, in terms of material and manpower. Administrative burdens and time-to-approval issues can also affect technology deployment and increase costs. The criteria upon which to evaluate technology performance, reliability and safety provides those seeking to move ESS into the market and those responsible for public safety, a framework on which to base a determination that the system and its installation are "safe." As existing CSR are updated and/or new CSR are developed that specifically address the range of ESS technologies and installations and those CSR are adopted, it becomes easier to document what is safe and determine what can be approved in a uniform and timely manner. Some resent efforts in advancing CSRs for energy storage include: The 2017 National Electrical Code Article 706 on Energy Storage, Underwriters Laboratories development of UL9540 on Energy Storage Systems and Equipment, and the announcement by the National Fire Protection Agency of plans to develop a new standard addressing the design, construction, installation, and commissioning of stationary energy storage systems.

Research and development

- Materials Science R&D
  The topic of Li-ion battery safety is rapidly gaining attention as the number of battery incidents increases. Research is underway to find materials with the necessary properties, especially the required thermal behavior, to ensure fail-proof operation. The main failure modes for these battery systems are either latent (manufacturing defects, operational heating, etc.) or abusive (mechanical, electrical, or thermal).
- Engineering controls and system design
  The monitoring needs of batteries, as well as effectiveness of means to separate battery cells and modules, or various fire suppression systems and techniques in systems is being studied extensively. Detailed testing and modeling are being done to fully understand the needs in system monitoring and containment of failure propagation. Rigorous design of safety features that adequately address potential failures are under development in most technology areas.

- Modeling
  An energy storage system deployed on the grid, whether at the residential (<10kW) or bulk generation scale on the order of MW, is susceptible to similar failures as described above for Li-ion. In order to ensure safety as grid storage systems are deployed, research is underway to understand their potential failure modes within each deployment environment. The size and the variety of technologies necessitate the further development of model based safety validation techniques for large scale systems.
- System testing and analysis
  Validation techniques are guided primarily by CSR. Standard validation techniques are most evolved in the areas of lead-acid and Lithium-ion battery technologies due to their use in vehicle technologies. To date this work has been only reached maturity in the vehicle battery space, and work is being done to reapply testing methods to grid storage. Tests are being develop at every level of the system, shown in Figure 2, to validate systems safety.

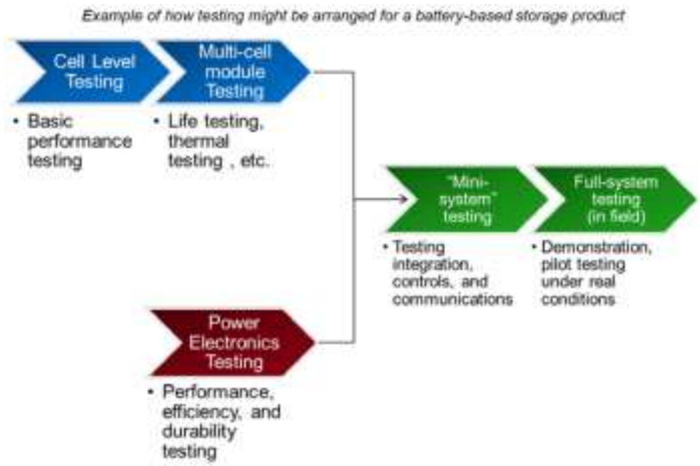


Figure 2 Levels of integration at which safety validating testing is performed

Emergency Preparedness

Incident preparedness activities can be divided into two categories: engineered controls and administrative controls. Administrative controls include activities such as pre-planning for an incident, codes and standards, and risk management tools. Engineered controls include aspects of the system and its installation such as fire suppression, storage system design, and fail-safes.

- Engineered controls
  The first step in ensuring safety of any system is to ensure that the system is designed to the highest possible level of safety. The engineering of safety into a system must start at the materials level and be designed all the way through to deployment. Fixed facilities may have the added benefit of fire suppression systems, central station alarm monitoring, emergency power-off systems, site access control, ventilation systems, and on-site facilities or trained engineering staff. Current fixed-facility suppression systems utilize extinguishing agents that typically include water mist, dry chemical, CO_2, or other inert gas agents. Challenges include the increased commodity storage, R&D complication issues due to experimental processes and/or procedures,

and fire service access issues. The staffing model of the local fire department, available water supply, and level of ES awareness possessed by the responders can either positively or negatively impact any of the aforementioned challenges.

- Administrative controls
  Two main components of the administrative controls for energy storage system safety are the emergency preparedness plans and the CSRs. The former guides first responders as to what actions to take in an emergency, and the latter dictates the facility signage, processes and procedures. Because of the low frequency of energy storage incidents, the wide variety systems sizes and technologies, and deployment options work is underway to develop comprehensive emergency preparedness plans. These plans begin with what is commonly referred to as a Community Risk Assessment (CRA) to identify potential emergency scenarios. The scenarios addressed in the CRA must be based on the energy storage system characteristics and application space, and must comply with OSHA requirements (Appendix A). The property owner/occupant develops several incident-specific response plans, based on the CRA. These plans identify performance objectives and action steps to support the local incident scenarios and can include fire pre-incident plans created by first-response organizations. The pre-incident plans are typically based on several factors: fire department resources, unique or higher risk properties from an occupancy classification, life hazard, and special event. These pre-incident plans can include a casual building familiarization tour to a formal document complete with maps, fire control system locations, utility connections, high hazard contents, and building contact information. None of these elements by themselves should be considered adequate pre-incident planning, as all of them are fundamental requirements of pre-incident planning.

Conclusion

Grid energy storage systems are “enabling technologies”; they do not generate electricity, but they do enable critical advances to modernize the electric grid. This fact sheet provides information to help ensure the safety of energy storage deployments and instill confidence in the community of stakeholders who depend on an efficient, reliable and resilient electric grid. Energy storage systems come in many types, sizes and levels of technological maturity. Codes standards and regulations are being developed and updated to keep pace with the rapid pace of energy storage deployment. Significant research and development is underway to develop fail-safe materials, precise safety models, and advances testing programs to validate safety of integrated systems. Engineered and administrative controls are being developed to help local first responders prepare for safety incidents involving energy storage systems. All of these efforts together help to build stakeholder confidence in the safety, reliability, and security of electrical energy storage serving their local power grid.